CORROSION PREVENTION OF STEEL SAMPLE IN AQUEOUS SOLUTIONS AND ITS MECHANICAL PROPERTIES

YEAP LEONG HOOI

Report submitted in partial fulfilment of the
requirements for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

6 DECEMBER 2010

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature :
Name of Supervisor : LEE GIOK CHUI
Position : LECTURER OF FACULTY OF MECHANICAL ENGINEERING
Date : 6 DECEMBER 2010

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurently submitted for award of other degree.

Signature :
Name : YEAP LEONG HOOI
ID Number : MA 07018
Date : 6 DECEMBER 2010

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my Final Year Project supervisor, Mr. Lee Giok Chui, SMP, KMN. for his invaluable guidance and adviced during the process of the preparation of this thesis. Mr. Lee not only served as my supervisor but also as a spiritual counselor who always encourage me throughout the process. Besides that, I would like to express my special thanks to the panel member that gave me the valuable comment and suggestion during my Final Year Project 1 presentation.

Apart of this, a sincere thanks goes to Dr Syahrizan Bin Ahmad and all laboratory assistant from Faculty of Mechanical Engineering University Malaysia Pahang for their teaching and helping during the period of my Final Year Project.

Last but not least, I acknowledge my sincere indebtedness and gratitude to my parents, Mr. Yeap Beow Chuan and Mdm. Then Mee Yoon for their love and sacrifice throughout my life. They have always support my dreams and endless caring to me. They did a fine job in raising me up. My sister, Ms. Yeap Li Chian should be also recognized for her support along my Final Year Project.

ABSTRACT

Corrosion has become a main issue for all engineering sector in these few decades. The main purpose of this project is to investigate the corrosion prevention method in order to slow down the process of corrosion and to investigate the effect of the prevention method on the mechanical properties of those sample specimens. Three methods applied on the steel samples which are nickel electroplating, zinc electroplating and powder coating. The corrosion rate was determined by using weight loss method in immersion test according to ASTM G31, whereas the mechanical properties to be investigated were hardness and tensile test. The dimension of tensile test specimens was followed the ASTM E-8M. The results obtained show that the corrosion rate of the coated specimen was lower than that of the specimen without coating. The specimen with nickel electroplating has the lowest corrosion rate among the coated specimens, followed by powder coating and zinc electroplating. The coated specimens also have the higher value in hardness; yield strength and ultimate tensile strength, where the nickel electroplating has the highest value among all others specimens.

ABSTRAK

Pengaratan telah menjadi satu isu yang penting dalam sektor kejuruteraan pada kebelakangan dekad ini. Matlamat utama projek ini adalah untuk menyiasat kaedah-kaedah untuk mengelakkan kejadian pengaratan dan kesan kaedah-kaedah tersebut pada sifat-sifat mekanikal. Kaedah yang digunakan untuk mengelakkan berlakunya pengaratan ialah elektroplating nikel, elektroplating zink dan pelapisan serbuk. Kadar pengaratan ditentukan dengan menggunakan pengurangan berat dalam ujian perendaman mengikut standard ASTM G31, manakala sifat-sifat mekanikal adalah ditentukan dengan menggunakan ujian kekerasan dan ujian penarikan. Dimensi sampel-sampel ujian adalah mengikut standard ASTM E-8M. Keputusan menunjukkan bahawa kadar pengaratan sampel-sampel yang telah dilapiskan adalah lebih rendah daripada sampel yang tiada dilapiskan. Sampel-sampel yang telah dilapiskan juga menunjukkan bahawa sampel-sampel tersebut menpunyai nilai yang lebih tinggi dalam ujian kekerasan dan ujian penarikan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AISI	American Iron and Steel Institute
ASTM	American Society for Testing and Materials
ASTM E8-M	Standard Test Methods for Tension Testing of Metallic Materials
ASTM G1	Practice for preparing, cleaning and evaluating corrosion test specimens
ASTM G31	Standard practice for laboratory immersion corrosion testing of metals
TGIC	Triglycidyl isocyanurate
VOC	Volatile Organic Compounds

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The term corrosion has its origin in Latin. The Latin term rodere means 'gnawing' and corrodere mean 'gnawing to pieces' [5]. It is rather interesting to examine the historical aspect of the developments of corrosion. Metallic corrosion has no doubt been a problem since common metals were first put to use. Most metals occur in nature as compounds, such as oxides, sulfides, silicates, and carbonates. There are very few metals occur in native form. The obvious reason is the thermodynamic stability of the compounds as opposed to the metals. The process of extraction of a metal from the ore is reduction. The equation of the reduction is as below:

$$2Fe_2O_3 + 3C \longrightarrow 4Fe + 3CO_2$$

In the extraction of the iron, the oxide is reduced to metallic iron. On the other hand, the oxidation of iron to produce the brown iron oxide commonly known as rust is the opposite reaction to the production of the metal from the oxide. The extraction of iron from the oxide, must be conducted with utmost careful control of the conditions, such that the backward reaction is prevented. There are many types of corrosion such as below:

- Uniform corrosion
- Galvanic corrosion
- Crevice corrosion

- Pitting corrosion
- Hydrogen damage
- Intergranular corrosion
- Dealloying
- Erosion corrosion

Corrosion has a big impact on the material. It will weaken the bond among the material. At the same time, it also affects the mechanical properties of the material such as the tensile strain, hardness and etc. Apart of this, corrosion also has an impact on the safety factor. The well known bridge collapse at Pt. Pleasant, West Virginia, killed 46 in 1967 and has been attributed to stress corrosion cracking [5].

Besides that, corrosion has another impact which was the economy impact. The US Federal Highway Administration released a study, entitled Corrosion Costs and Preventive Strategies in the United States, in 2002 on the direct costs associated with metallic corrosion in nearly every U.S. industry sector. The study showed that for 1998 the total annual estimated direct cost of corrosion in the U.S. was approximately $276 billion (approximately 3.1% of the US gross domestic product).

Jones writes that electrochemical corrosion causes between $8 billion and $128 billion in economic damage per year in the United States alone, due to degrading structures, machines, and containers. Therefore, the corrosion prevention is important in order to save cost.

For corrosion prevention, there are many preventive methods. For examples:

- Cathodic protection
- Powder coating
- Inhibitors
- Electroplating

Each of the above method can be used to protect the material lifespan and its mechanical properties. All these methods can prevent the corrosion happen for a short period, and at the same time, they do give an extra mechanical properties on the material.

This project investigates the mechanical properties of mild steel after corrosion prevention. The methods used were zinc electroplating, nickel electroplating, quenching of mild steel and powder coating. The mechanical properties such as tensile and bending after a given period were being investigated after a certain period of exposure.

1.2 PROBLEM STATEMENT

Corrosion is a main issue for all engineering sector in these few decades. People are spending a lot of time to study and investigate about the corrosion and its effect. Companies even raised up the fund to investigate the prevention of corrosion as to minimize the cost of replacing the corroded material in their usage. Corrosion will cause the breakdown of the structure of the buildings or machine. This is very dangerous for the people who are using the buildings or the machine. Corrosion will also cause downtime on the machine and this will give a big impact for manufacturing companies in earning.

1.3 OBJECTIVES

The main objective on this project is to investigate the corrosion rate of the material after the prevention method is applied on it. Secondly, is to investigate the mechanical properties of the material after the application of corrosion prevention.

1.4 SCOPES

In this project, there are few sectors being investigated. The literature review is mainly focused on the corrosion types which were general corrosion and pitting corrosion and its prevention methods. Besides that, there were also reviewed on the corrosion rate and techniques on how to apply the prevention method and the experiment to carry out.

The corrosion rate of the specimens was calculated by using weight loss method. The experiment was carried out by using immersion test follow the ASTM standard, which was ASTM G31. There were two mechanical properties been investigated, which were the tensile and the hardness of the specimens. The results of from all the collected data from the experiments mentioned above were being analyzed. Graphs were plotted by using the data obtained and been studied.

After all the experiments, the results were being compared and analyzed. After all testing and analysis was done, it came out with a conclusion about the objective of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

There are some previous studies on the mechanical properties of the mild steel AISI 1010 based on the corrosion is being reviewed in this chapter. Through this paper, the description of the corrosion type and the prevention method of the corrosion was discussed generally at the early part of this chapter. Then, the mechanical properties of the mild steel AISI 1010 and some machine that used are also being discussed in this chapter.

2.2 CORROSION

Corrosion is defined as the destructive result of the chemical reaction between a metal or metallic alloy and its environment. Metal atoms in nature are present in chemical compounds (i.e. minerals). The same amounts of energy needed to extract metals from their minerals are emitted during the chemical reactions that produce corrosion, Corrosion returns the metal to its combined state in chemical compounds that are similar or even identical to the minerals from which the metals were extracted. Thus, corrosion has been called extractive metallurgy in reverse [1].

Many nonmetallic materials, such as ceramics, consists of metals that have their chemical reactivity satisfied by the formation of bonds with other reactive ions, such as oxides and silicates. Thus, such materials are chemically unreactive, and they degrade by physical breakdown at high temperature or by mechanical wear or erosion.

Similarly, the organic polymers(plastics) are relatively unreactive because they have very stable covalent bonding, primarily formed between carbon atoms.

2.3 CORROSION TYPES

Corrosion happens everywhere and everyday around us. There are a lot of different forms of the corrosion and there are eight most common form which are:

(1) uniform, or general attack,
(2) galvanic, or two-metal corrosion,
(3) crevice corrosion,
(4) pitting,
(5) intergranular corrosion,
(6) dealloying,
(7) erosion corrosion, and
(8) stress corrosion cracking.

2.3.1 Uniform or general attack

This is also called general corrosion. The surface effect produced by most direct chemical attacks (e.g., as by an acid) is a uniform etching of the metal. On a polished surface, this type of corrosion is first seen as a general dulling of the surface and, if allowed to continue, the surface becomes rough and possibly frosted in appearance.

While this is the most common form of corrosion, it is generally of little engineering significance, because structures will normally become unsightly and attract maintenance long before they become structurally affected.

Figure 2.1: Picture show how this corrosion can progress if control measures are not taken. [1]

(Source: NASA Corrosion Technology Laboratory)

2.3.2 Galvanic, or two-metal corrosion

Galvanic corrosion is an electrochemical action of two dissimilar metals in the presence of an electrolyte and an electron conductive path. It happened when there are two or more dissimilar metals are in contact.

Table 2.1: Galvanic series in seawater [1]

(Source: NASA Corrosion Technology Laboratory)

Galvanic Series In Sea Water	
	Noble (least active)
Platinum	
Gold	
Graphite	
Silver	
18-8-3 Stainless steel, type 316 (passive)	
18-8 Stainless steel, type 304 (passive)	
Titanium	
13 percent chromium stainless steel, type 410 (passive)	
7NI-33Cu alloy	
75NI-16Cr-7Fe alloy (passive)	
Nickel (passive)	
Silver solder	
M-Bronze	
G-Bronze	
70-30 cupro-nickel	
Silicon bronze	
Copper	
Red brass	
Aluminum bronze	
Admiralty brass	
Yellow brass	
76NI-16Cr-7Fe alloy (active)	
Nickel (active)	
Naval brass	